National Program 303 • PLANT DISEASES
FY 2014 Annual Report

National Program 303, Plant Diseases, focuses on developing effective disease management strategies that are environmentally friendly, safe for consumers, and compatible with sustainable and profitable crop production. This USDA-Agricultural Research Service (ARS) National Program is conducted in cooperation with related research in other public and private institutions. In particular, NP 303 projects are coordinated with those in National Program 301 (Plant Genetic Resources, Genomics, and Genetic Improvement) toward the overall goal of crop improvement through increased resistance to biotic and abiotic factors and increased understanding of host-pathogen interactions.

The overall goal of NP 303 is to develop and improve ways to reduce crop losses caused by plant diseases, while safeguarding the environment. To this end, projects in this national program aim to reduce the impact of diseases on yields, product quality or shelf-life, aesthetic or nutritional value, and potential contamination of food and feed with toxins.

Management of plant diseases is essential for providing an adequate and consistent supply of food, feed, fiber, and aesthetic plants, and has long been a high priority for ARS. Besides the obvious monetary benefits to producers and processors, successful plant health protection is important for maintaining and increasing food supplies with minimal increases in land under cultivation. Additionally, the knowledge and management of plant diseases of quarantine significance are vital, not only for protecting our domestic crops from foreign disease, but also for maintaining and expanding export markets for plants and plant products.

NP 303 consists of 59 projects located in 19 different states. Most of the more than 130 scientists working within this national program are specialists in plant pathology and/or nematology. Significant contributions to NP 303 also come through multidisciplinary teams that include geneticists, agronomists, botanists, horticulturists, physiologists, soil scientists, entomologists, chemists, and microbiologists.

NP 303 is comprised of the following four components:

- *Diagnostics, Etiology, and Systematics*
- *Biology and Epidemiology of Plant Disease*
- *Plant Health Management*
- *Alternatives to Preplant Methyl Bromide Soil Fumigation*

Together, these components include research to understand and control plant diseases and to develop and transfer strategies for disease management and control that enhance agricultural production and value. During fiscal year 2014, this program produced many important discoveries and advances. Some of these are described below, grouped by program component.

Component 1 – Diagnostics, Etiology, and Systematics

Increasing access to new genetic resources to protect sugarcane. Sugarcane producers and industry need access to new genetic crop diversity to thwart numerous endemic and invasive pests, to diversify onto marginal land, and to adapt to climatic change. However, sugarcane germplasm imports to the United States have been restricted to “seed cane,” or cane pieces, which has limited U.S. access to genetic diversity. In 2014, ARS scientists in Houma, Louisiana, and in Canal Point, Florida, working with university and international sugarcane researchers, determined the risk of importing pathogens on true seed (termed “fuzz”), which was previously unknown. All test results were negative, and no seedling from parents infected with known pathogens was found to be infected. These results contributed to a decision made by APHIS that fuzz can now be imported into the United States under approved protocols. The result is that major new genetic diversity can now be provided to all sugarcane breeding projects in the United States which will help cane producers manage disease, respond to climate challenges, and protect profits.

Discovery of a major group of beneficial nematodes. Although many nematodes cause significant crop losses, other species feeding on fungi or other microorganisms are beneficial to agriculture. One major agricultural problem is that the beneficial species of nematodes that might be used as biological control are often unknown. ARS scientists in Beltsville, Maryland, in collaboration with scientists from England, described six new species of nematodes (called Rugoster species) associated with rice, weeds, and forests in Nigeria, Ivory Coast, India, and Australia. They also developed a new diagnostic key for identifying these nematodes and related species. This key can help scientists advance the use of beneficial nematodes in agricultural soils.

First report in North America of Cucumber green mottle mosaic virus (CGMMV), an emerging disease of the cucurbit family. ARS researchers in Charleston, South Carolina, discovered CGMMV infecting greenhouse cucumbers from Alberta, Canada. This seed- and soil-borne virus was subsequently identified by others in cucurbit seed production fields in California, causing a major concern to the vegetable seed industry and cucurbit producers in the United States. CGMMV is primarily limited to cucurbit species, including watermelon, melon, cucumber, pumpkin, squash, and gourds. CGMMV can be especially problematic due to the ease with which it is transmitted and its stability and long viability in plant debris, in soil, or on greenhouse or equipment surfaces. The damage it causes to the host plant and fruit can be extensive, resulting in substantial yield losses, and limited resistance to the virus exists in commercial cultivars. A real-time molecuar diagnostic method was developed by the researchers, which reliably detects CGMMV isolates and which can be applied for seed and plant health tests.

Identification and characterization of new and emerging maize viruses. Virus populations in U.S. corn and wheat have not been surveyed in Ohio for several decades, but the high-impact outbreak of Maize Lethal Necrosis virus in East Africa now requires monitoring and rapid pathogen detection in the United States. ARS researchers in Wooster, Ohio, surveyed and used DNA genome sequence data from maize and wheat viruses in the United States and East Africa, working with Ohio State University bioinformaticists, to develop an in-house plant virus DNA identification pipeline. Partial and complete genome sequence data for maize viruses were obtained, including African isolates of Maize Chlorotic Mottle Virus and Sugarcane Mosaic Virus and Ohio isolates of the major U.S. maize viruses, Maize Chlorotic Dwarf Virus and Maize Dwarf Mosaic Virus, as well as new viruses including a maize luteovirus in Africa and the first appearance of Wheat Mosaic Virus (causal agent of High Plains disease) in Ohio. Development of these new DNA methods that identify corn and wheat viruses will enable rapid detection of viral strains in the U.S. and help researchers develop more effective control methods to protect corn and wheat from disease losses.

Co-infection by the two major U.S. maize viruses prolongs disease symptoms. Two major U.S. maize viruses, Maize chlorotic dwarf virus (MCDV) and Maize dwarf mosaic virus (MDMV), overlap in distribution and frequently occur in co-infections; however, the impact, if any, of co-infection on corn disease damage was unknown. ARS researchers in Wooster, Ohio, assessed co-infection of these two viruses. Whereas young plants infected with a single virus showed some reduction in symptom severity over time, plants co-infected with the severe strain of MCDV (MCDV-S) and MDMV continued to show severe symptoms over a month after infection. Unlike some pairs of co-infecting viruses that cause extremely severe disease, the combination of the two major U.S. maize viruses may have implications for disease losses but does not result in plant death under the test conditions. These results will be used by other corn researchers to determine better approaches for disease management and make recommendations for the best corn varieties to grow in regions at risk to maize viruses.

New screening method for severe strains of Citrus tristeza virus (CTV). CTV is a regulated pathogen by the California Department of Food and Agriculture, and it is controlled in central California by removal of trees infected with severe CTV strains. CTV is detected by reaction with a specific monoclonal antibody ("MCA13"). But, greenhouse biological assays showed only a small portion of the MCA13-positive isolates in central California caused severe disease symptoms. Therefore, ARS scientists in Parlier, California, developed molecular methods to discriminate potentially severe strains. The Central California Tristeza Eradication Agency, a grower-funded organization that surveys for CTV, now sends CTV isolates that are positive by reaction with the antibody MCA13 to ARS in Parlier for secondary screening to identify potential severe strains of CTV, thus reducing the number of trees that need removal.

Improved methods for identifying stunt nematodes. Nematodes cause crop diseases costing $100 billion annually worldwide. Stunt nematodes are one group that damages many kinds of plant roots. Existing methods for identifying different species of stunt nematodes are neither easy nor fast, so ARS scientists in Beltsville, Maryland, described improved methods for identifying two new and seventeen existing valid species of stunt and related nematodes from surveys conducted in cultivated and natural environments in Spain and in the United States. These advances combine anatomical features obtained with light microscopes and high-powered electron microscopes with DNA sequences and analysis of the phylogenetic or evolutionary relationships among the nematodes. Benefits of these new descriptive methods are significant because they provide valuable details that allow these species to be identified, and also provide the most complete phylogenetic analysis and groupings of stunt nematodes conducted so far. Consequently, this approach of integrating anatomical and DNA-based features provides an easy and rapid means for separating species of stunt nematodes from each other. This research will be used by research scientists, action agencies, and extension agencies involved in nematode research and control.

Component 2 – Biology and Epidemiology of Plant Disease

New technology provides nematode resistance in potatoes. Potato cyst nematodes (PCNs) are devastating pests impacting U.S. potato production which is valued at $4 billion. Methods for effective PCN control are limited and often rely on toxic chemicals for soil fumigation, so there is a major need to develop new methods to protect potatoes from these nematodes. ARS researchers in Ithaca, New York, have identified genes critical for nematode infection. They have employed a plant mediated RNAi technology to silence these nematode genes, which resulted in the development of a nematode resistant potato cultivar. This technology, which was patented, provides a valuable new tool for plant researchers working to protect potato growers and the industry from costly nematode losses.

New discovery of the genetic factors that confer Ug99 wheat stem rust resistance. Ug99 wheat stem rust has not yet been found in the United States, but it is spreading overseas and is considered a potential threat to up to 90 percent of the wheat varieties currently available that do not have genetic resistance. Durable resistance to wheat stem rust in adult wheat plants is highly desired to protect wheat production from major stem rust losses. In 2014, ARS scientists in St. Paul, Minnesota, identified and determined that a combination of genetic factors can confer adult resistance to wheat stem rust in wheat varieties adapted for the United States. These results can be used by wheat breeders to develop new wheat varieties with even more effective genetic resistance to Ug99 and other wheat stem rusts.

A Universal Plant Virus Microarray (UPVM) for the detection and identification of all known plant viruses. ARS scientists in Beltsville, Maryland, have built upon existing disease classification systems to develop a Universal Plant Virus Microarray (UPVM) that recognizes all known plant viruses. This virus detection microarray contains DNA material collected from 9,556 individual virus-specific probes, and it was validated for at least 44 plant virus genera and taxonomic groups representing at least 15 virus families. In addition, the correct genus was identified for two recently-described viruses not represented by species-specific probes. This new assay will be especially valuable for detecting viruses in plants imported to the United States.

Identification of fungicide resistance in the sugarbeet pathogen powdery mildew. In the western United States, sugarbeet yields can be reduced by fungal infections of powdery mildew. The quinone outside inhibitor (QoI) class of fungicides is typically used to control powdery mildew, but in some experimental plots near Parma, Idaho, researchers noted a reduction in its efficacy. ARS scientists in Fargo, North Dakota, and industry plant pathologists determined that this is the first identification of QoI resistance in powdery mildew in the United States. They also identified a specific gene mutation in all QoI-resistant strains of the fungus, a discovery that provides the foundation for using molecular-based techniques to identify QoI-resistance. These findings will enhance efforts to manage fungicide resistance in sugarbeet production and support efforts to optimize fungicide rotations for effective disease control.

The release of Huckleberry Gold, a new nematode-resistant potato cultivar. The potato cyst nematode (PCN) is increasingly responsible for economic losses in the U.S. potato industry, and the most effective and environmentally sound approach for controlling the PCN is improving host resistance. ARS researchers in Ithaca, New York, in collaboration with potato breeders in Aberdeen, Idaho, have developed Huckleberry Gold, a specialty market potato cultivar with resistance to PCN and potato virus X. Potato producers can use this new resistant cultivar to reduce losses associated with PCN and support eradication efforts in the United States.

Wheat cultivar, 'Thatcher,' is believed to be the source of adult plant resistance (APR) in United States spring wheat. The genetics of resistance in the wheat cultivar, 'Thatcher,' which has durable adult plant resistance to stem rusts has been determined to be based on the complementary interaction of 3 genetic factors. Scientists at the ARS Cereal Disease Laboratory in St. Paul, Minnesota, observed a reduction in stem rust severity when two or three of these quantitative trait locus (QTL) factors were present. In addition, resistance was enhanced by the gene Sr57 (Lr34). Knowledge of the identified QTL, the co-localization of one of these QTL with the defeated stem rust resistance gene Sr12, and the complementary gene action observed by these factors provide valuable information needed to select for adult plant resistance in U.S. spring wheat. Additionally, the resistance derived from cultivar 'Thatcher' can confer high levels of APR to the virulent race (Ug99) of stem rust when combined with the stem rust resistance gene Sr57 (Lr34).

Powdery mildew resistant bottle gourd germplasm lines for use as rootstocks for watermelon. Powdery mildew is a serious disease that affects all cucurbit species and significantly reduces yield and marketable fruit quality in the United States and across the world. Bottle gourds are used as rootstocks for grafting watermelon plants to manage various soil-borne diseases such as Fusarium wilt; however, the rootstocks are prone to foliar diseases such as powdery mildew. ARS scientists developed two bottle gourd germplasm lines with resistance to powdery mildew. Development of varieties and rootstocks with resistance to powdery mildew will reduce fungicide use and allow producers to grow a successful crop. Powdery mildew resistant bottle gourd germplasm lines will be useful in developing commercial resistant watermelon rootstocks for watermelon grafting, and will be useful for developing resistant bottle gourd varieties with fruit that are used for human consumption in Asia.

Plantago asiatica mosaic virus (PlAMV) detected in lily bulbs imported from the Netherlands. In 2011, imports of ornamental bulbs (mainly tulips, hyacinth, narcissus, and lilies) from the Netherlands were valued at $160 million and accounted for 10.4 percent of imports. ARS scientists in Beltsville, Maryland, identified PlAMV for the first time in lily bulbs imported from the Netherlands in 2014. As a result of this finding, the Dutch flower bulb testing service expanded its facility in anticipation of a significant increase in samples for virus indexing. Diagnostic methods for PlAMV, developed by ARS scientists in Beltsville have been validated by USDA-APHIS. Further knowledge of the length of soil survival of the virus and additional plant hosts will be key in generating virus-free bulbs through tissue culture. Discussion with Canada (partners in the Preclearance program) is needed, but if necessary, APHIS can unilaterally request additional testing/certification of materials from the Netherlands under the Preclearance program.

Production of true seed in previously sterile potatoes. Development of new potato varieties requires cross pollination of plants with desirable traits, followed by seed production. Some highly useful potatoes cannot be used in breeding due to the inability to produce seeds. ARS researchers in Beltsville, Maryland, have discovered a gene that confers seed production to a previously sterile potato cultivar with desirable consumer attributes and superior disease resistance. As a result new genes for tuber color, nutrition, and disease resistance can be introgressed into diverse market cultivars. This discovery provides increased value to the consumer, and decreased costs for the producer.

Component 3 – Plant Health Management

National Sclerotinia Initiative develops effective screening tools to accelerate sclerotinia protection in sunflower. The sclerotinia diseases are some of the most important diseases of sunflower in the Northern Great Plains. ARS scientists in Fargo, North Dakota, together with Sclerotinia Initiative-funded collaborators, have developed a standardized regional approach to identify significant differences in the susceptibility of sunflower hybrids to sclerotinia. Building on that successful result, the researchers have developed field-scale inoculation procedures and misting systems that have enabled U.S. sunflower breeders to identify sunflower hybrids with resistance to sclerotinia. The system has been effectively implemented to assess sclerotinia resistance of newly released commercial hybrids at five regional "common garden" nurseries, providing growers with site-specific and overall performance characteristics of individual sunflower hybrids, and facilitating the release of new oilseed sunflower genetic lines with improved head rot resistance. The standardized assessments have significantly increased the number of hybrids identified with improved levels of sclerotinia resistance for U.S. sunflower growers whose 2012 crop production was valued at $727.8 million.

The citrus pathogen Xylella fastidiosa cannot be transmitted to seedlings through infected seed. Citrus variegated chlorosis, which is caused by Xylella fastidiosa, is an important bacterial disease of citrus in South America and a potential threat to citrus producers in the United States. ARS researchers in Beltsville, Maryland, collaborated with citrus researchers and Fundecitrus of Sao Paulo, Brazil, to determine if chlorosis can be transmitted by seed. Researchers at Fundecitrus extracted seeds from healthy and diseased sweet orange fruit and sent the seeds to Beltsville, where ARS researchers determined that the Xylella fastidiosa pathogen is not transmitted to seedlings through infected seed. The results provide new information on how citrus diseases are transmitted and help the citrus fruit producers involved in international trade manage threats posed by plant disease.

New soybean cultivar JTN-5110 has resistance to multiple pathogens. In the United States, combined soybean yield losses from the soybean cyst nematode (SCN) and several damaging fungal diseases (charcoal rot, stem canker, sudden death syndrome, and Frogeye leaf spot) are estimated to be nearly $1 billion. Although soybean cultivars with SCN resistance have stabilized some yield losses, nematode populations have evolved that are now able to infest the resistant cultivars. ARS researchers in Jackson, Tennessee, developed and released a new soybean line, JTN-5110, that yields from 62 to 66 bushels/acre and has resistance to SCN and the fungal diseases. Growers have been anticipating a cultivar with these combined traits and are adopting the new release for more effective SCN management. This release also is being used by soybean breeders as an excellent breeding parent to develop improved cultivars.

Protecting wheat from cereal cyst nematodes. Cyst nematodes are among several types of plant-parasitic nematodes that reduce yields in dryland wheat fields in the Pacific Northwest and cause over $50 million in annual losses. There are no chemical controls or resistant varieties to control this emerging pathogen. ARS scientists in Pullman, Washington, screened locally adapted germplasm and varieties for resistance in infested fields and optimized a greenhouse screening technique for resistance. Using these new methods, they were able to successfully identify resistant wheat varieties that can be immediately grown by producers to avoid nematode losses. Wheat breeders can now use these new screening methods to develop improved varieties with even better nematode protection.

Adapted varieties save wheat production in acid soils with aluminum toxicity. ARS scientists in Pullman, Washington, have determined that low soil pH and aluminum toxicity may be responsible for yield losses of up to 90 percent in over 50,000 acres of wheat in Washington and in Idaho. Producers can attempt to mitigate these conditions by growing triticale or heavily liming the soil, but neither option is cost-effective. In collaboration with scientists at Washington State University, ARS researchers evaluated wheat varieties adapted to these soil conditions and identified several aluminum-tolerant varieties that gave significantly improved yields. These findings provide wheat growers in this region with cost-effective alternatives for improving their production.

New adult-plant resistance gene identified for wheat stripe rust. Growing resistant cultivars is the most effective, economical, easy-to-use, and environmentally friendly approach for control of stripe rust, but new genes for effective resistance are needed to improve the durability of resistance in commercial cultivars. ARS scientists in Pullman, Washington, completed mapping of non-race specific, high-temperature adult-plant resistance in the spring wheat ‘PI 178759.’ This gene and linked molecular markers provide a new resource for wheat breeders that are breeding wheat cultivars with durable resistance to stripe rust.

Component 4 – Alternatives to Preplant Methyl Bromide Soil Fumigation

Anaerobic soil disinfestation as an alternative to methyl bromide fumigation. ARS scientists in Ft. Pierce, Florida, assessed the potential of anaerobic soil disinfestation (ASD) combined with soil solarization as an effective soilborne disease management approach. In the absence of methyl bromide soil fumigation for the production of vegetables using the raised-bed annual production system, ASD and soil solarization was shown to be an effective alternative to methyl bromide for soil disinfestation. A single crop of in-ground ornamentals can be produced using the method, but multi-crop plantings of cut flowers are not possible using a single ASD application per year, as was typically possible with methyl bromide fumigation. Nevertheless, the combination of ASD and soil solarization can be substituted for methyl bromide treatments for a single crop, giving growers a viable alternative to methyl bromide.

Fumigant-independent approaches in the control of crown gall disease. The causative agent of crown gall, the bacterium *Agrobacterium tumefaciens*, is an excellent and long term colonist of soil particles and host and non-host root systems alike. ARS scientists in Davis, California, conducted research on pre-plant treatment of soil using Anaerobic Soil Disinfestation (ASD), an alternative to chemical-based soil fumigation. ASD effectively reduced soil-borne populations of both fungal and bacterial pathogens below detection limits after a 28 day exposure. In addition, weed species were dramatically reduced for up to 4 months post ASD application. This fumigation-independent approach to controlling key rootstock infecting pathogens can help alleviate problems caused by crown gall for both nursery and orchard production of woody perennial tree crops in the United States.

Resistance of selected almond and stone fruit rootstock genotypes to the Prunus replant disease (PRD) complex. Successive plantings of almond and stone fruit orchards on a given site typically sustain poor tree growth and yield loss. ARS scientists in Davis, California, evaluated the resistance of 21 almond and stone fruit rootstock genotypes to PRD in a repeat field trial. Most rootstocks with only peach parentage exhibited little resistance to PRD, while peach × almond hybrid rootstocks were relatively resistant. Rootstocks with plum parentage varied in response. The PRD resistance profiles generated by these trials are facilitating rootstock breeding efforts, informing rootstock selections made by growers and nurseries, and helping to reduce reliance on soil fumigation.